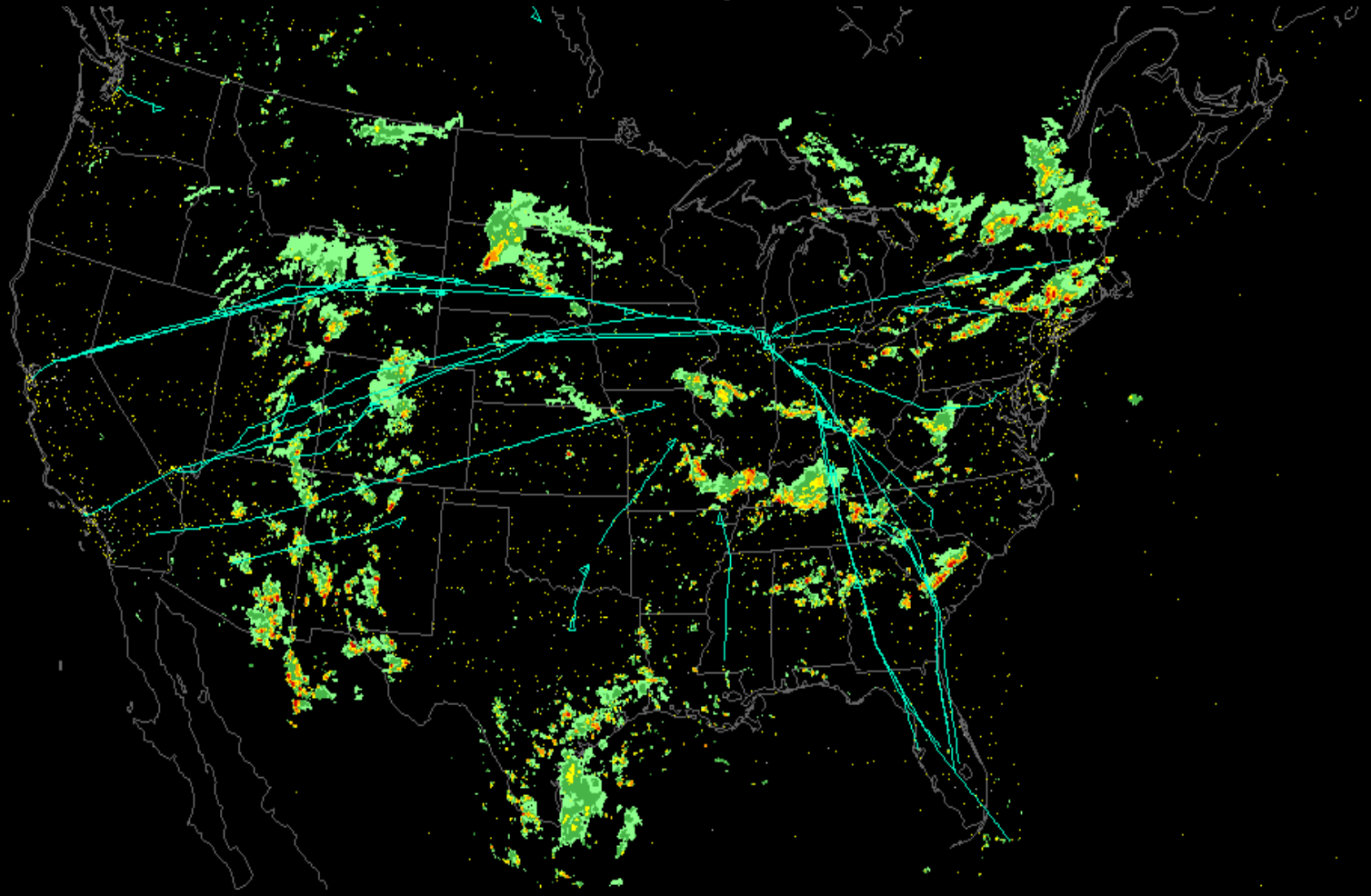
Traffic Flow Management Data Mining Update



Shon Grabbe
TFM Technical Lead

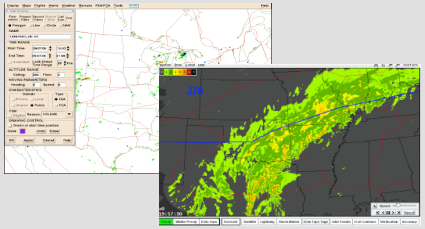
Research Objective

Given relevant NAS status, weather and traffic information determine the “best” collection of Traffic Management Initiatives to implement for day-of-operation planning purposes.

Work Sponsored By:
Richard Jehlen
Director, Planning and Procedures
FAA System Operations

Approach

Historical NAS Status, Weather and Traffic Information



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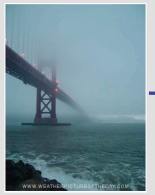

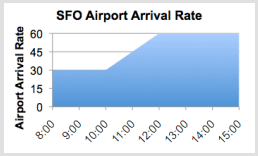

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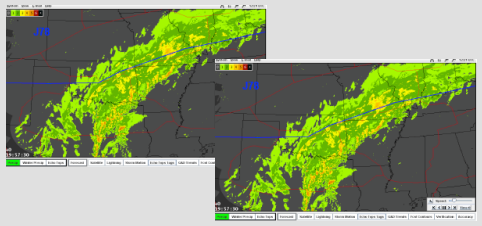

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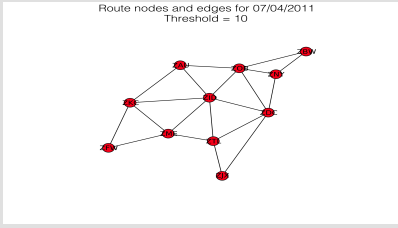

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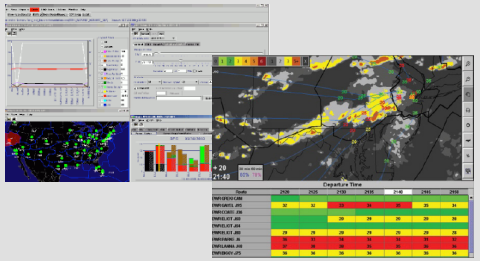

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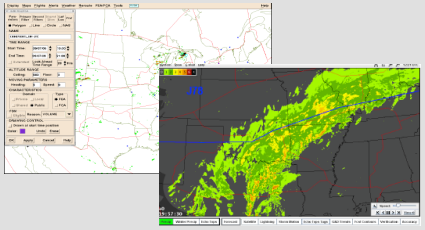
Historical NAS Status, Weather and Traffic Information



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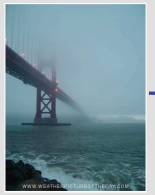

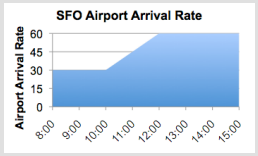

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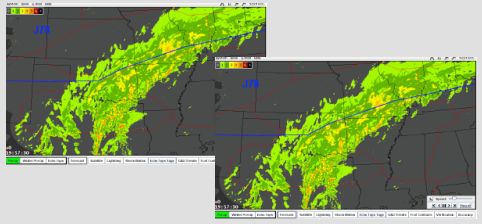

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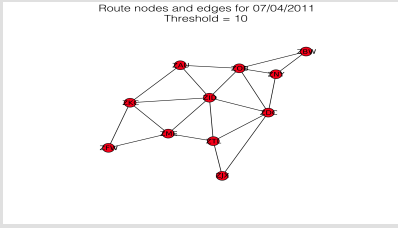

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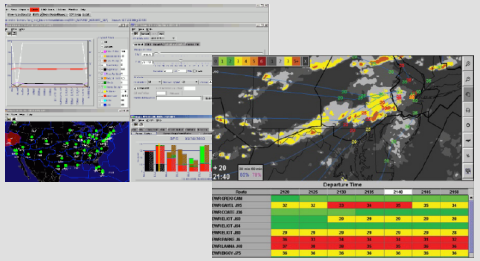
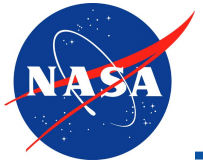




Historical NAS Status, Weather and Traffic Data

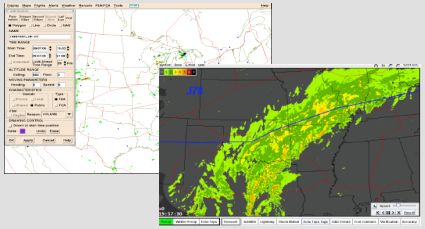
- Convective weather observations and forecasts are obtained through Corridor Integrated Weather Service (CIWS) archives

- Airport weather observations and forecasts obtained from METAR and TAF reports

- Aircraft Situation Display to Industry (ASDI) currently being used for traffic data

Approach

Historical NAS Status, Weather and Traffic Information



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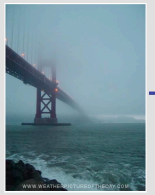

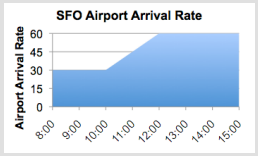

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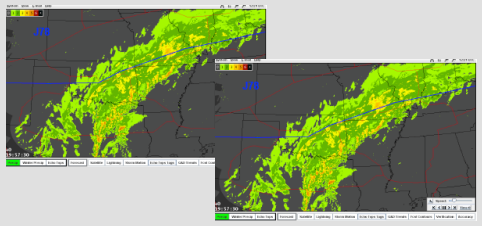

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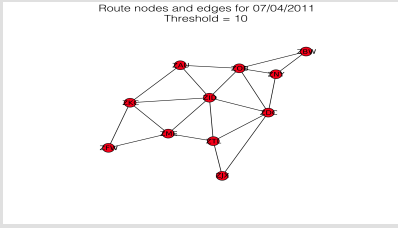

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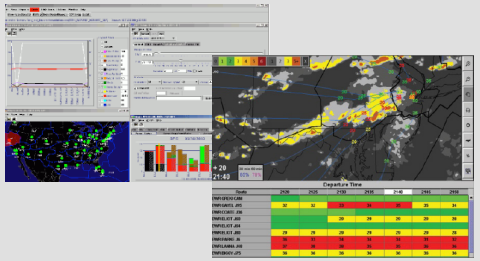
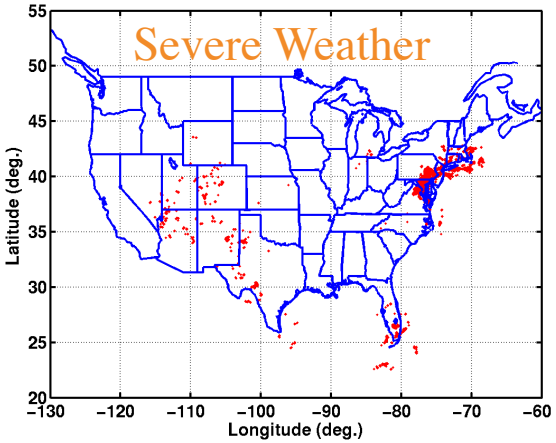
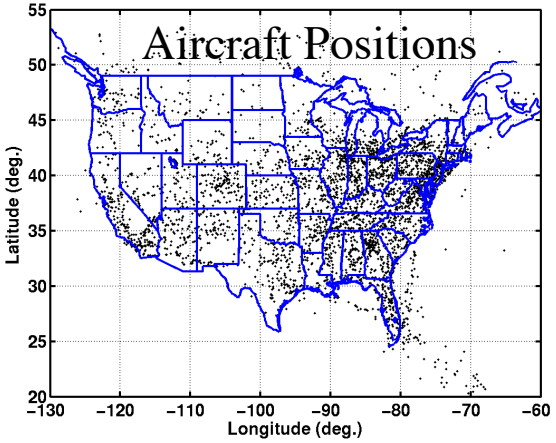


Simplified version of the Weather Impacted Traffic Index (WITI) used to estimate the impact of convective weather on en route air traffic



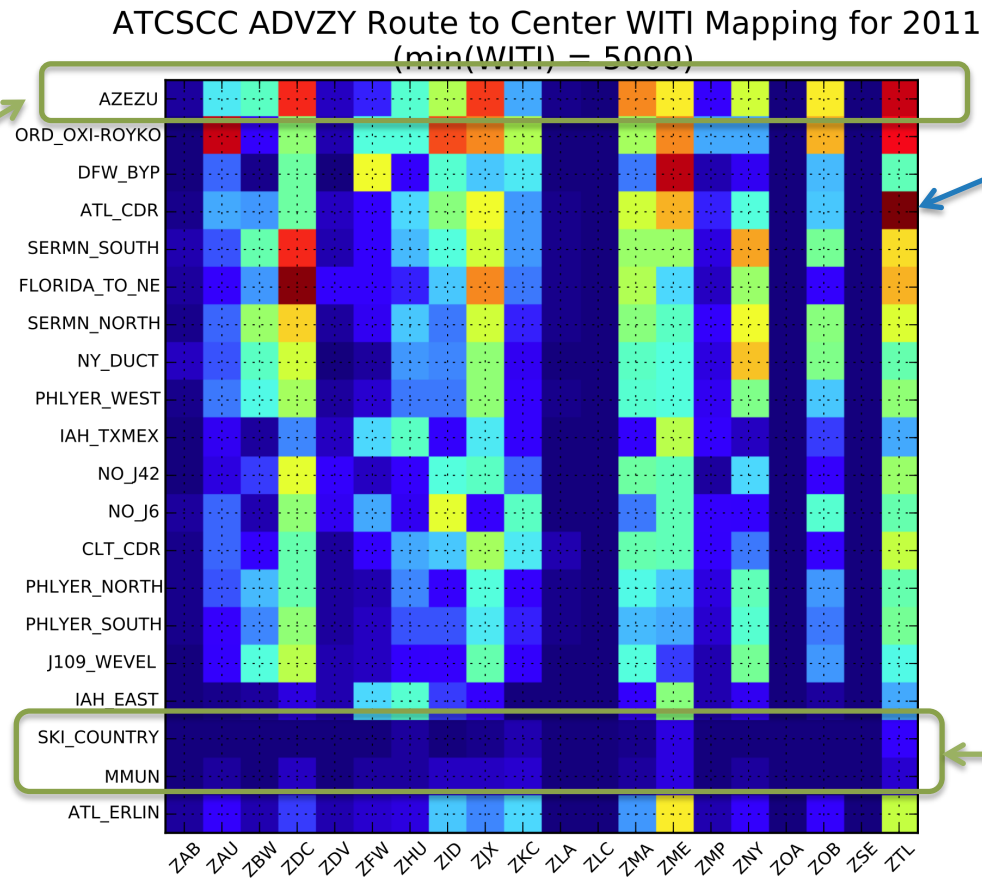


$$WITI(k) = \sum_{1 \le j \le m} \sum_{1 \le i \le n} T_{i,j}(k) W_{i,j}(k)$$

$W_{i,j} = 1$ at (i, j) locations with severe weather

$T_{i,j}$ = Traffic counts at (i, j) location

Airspace Weather Translation



Extensive routing on the east coast

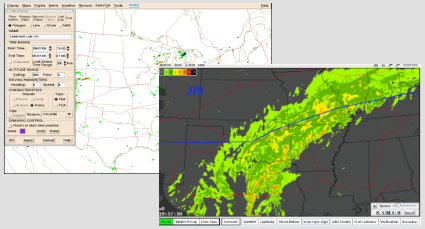
Color indicates the number of times that a particular reroute was used when the WITI in a particular Center was above a specified threshold value

Volume related reroutes

- Daily WITI used to capture the en route, convective weather impacts
- Additional features/attributes required for non-weather related reroutes (e.g, airport queuing delays)

Approach

Historical NAS Status, Weather and Traffic Information



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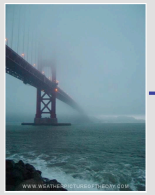

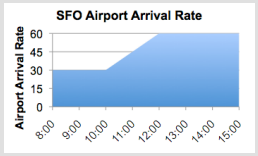

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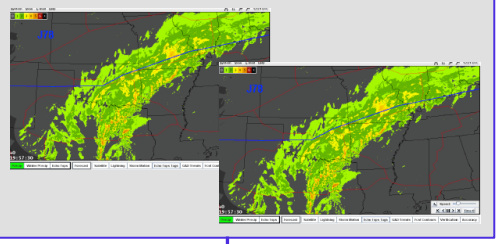

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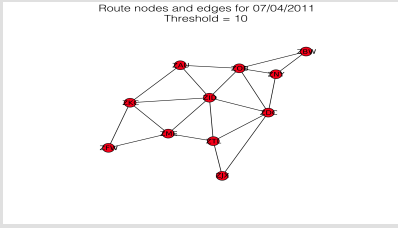

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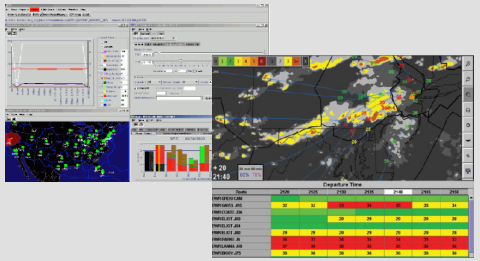
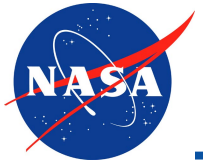


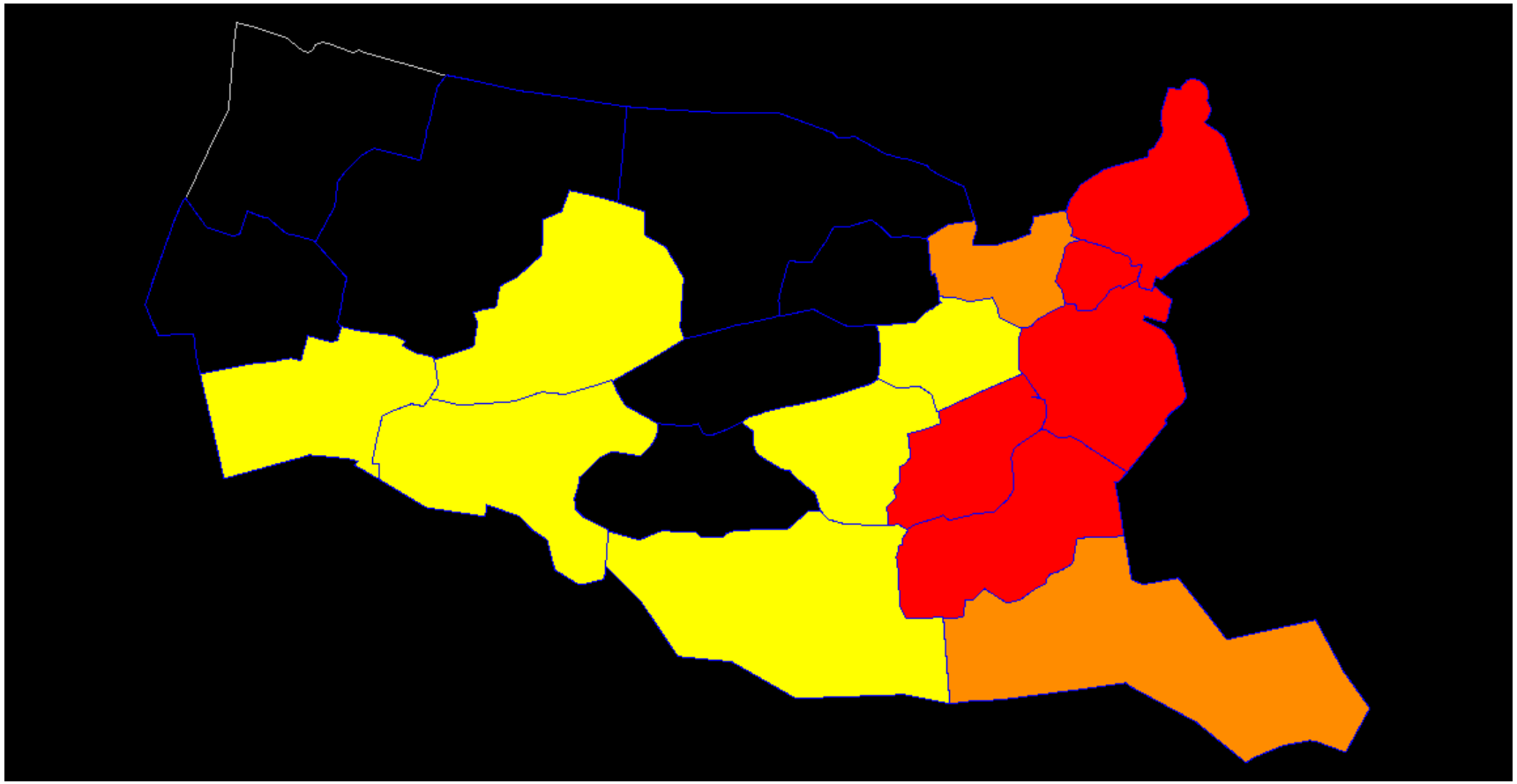


Airspace Weather Features

Clustering techniques can be used to reduce the number of en route features that are considered and subsequently simply the learning automation algorithms.

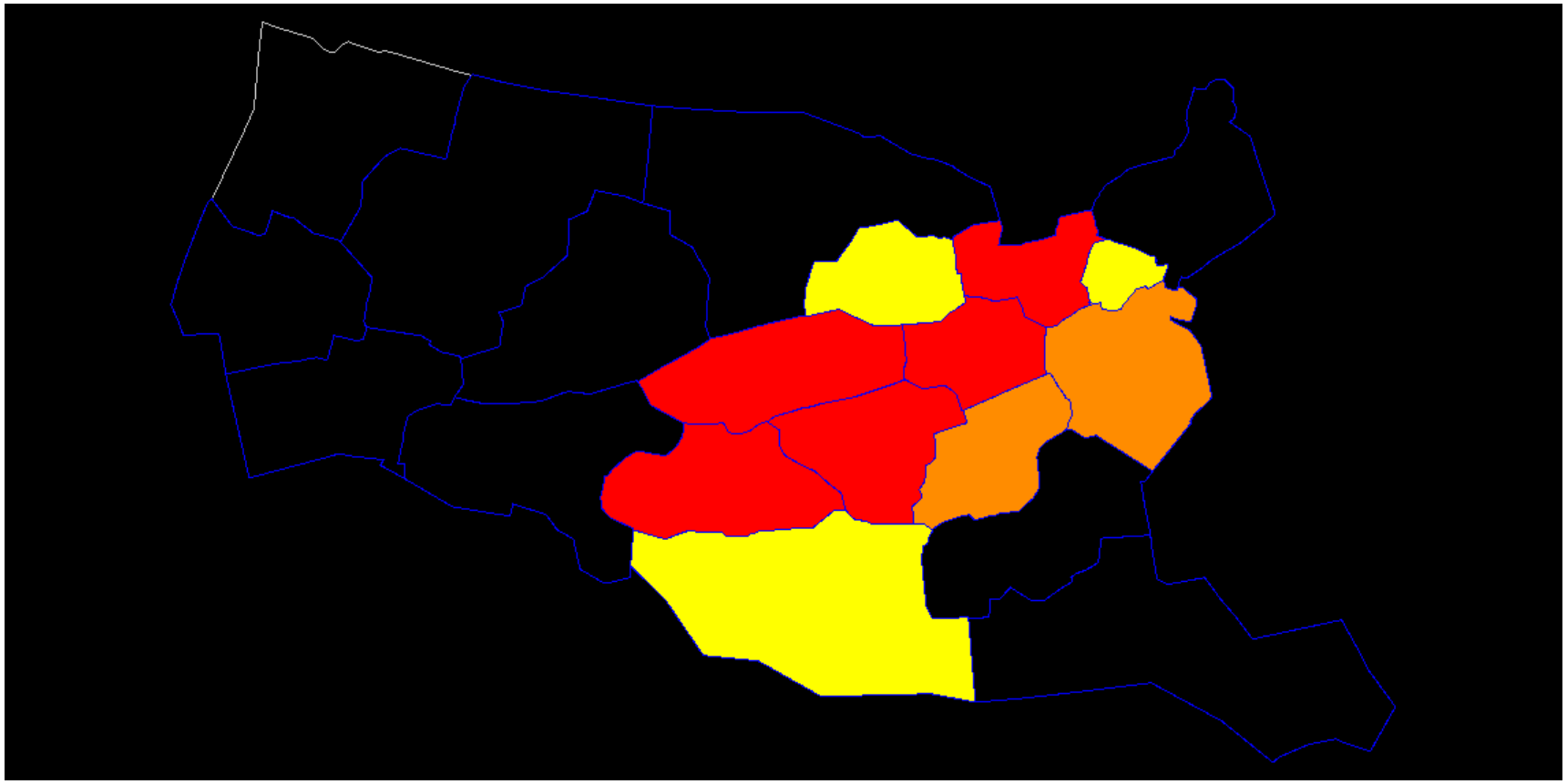
- Daily WITI of 20 Centers and Total NAS WITI used
- 321 days in 2011 used as input data
- WITI distribution obtained
  - Mean, variance, quartiles, 90th, and 95th percentiles
- WITI values standardized
- Perform cluster analysis. Extracted 17 clusters
- Attribute each day to a specific cluster
  - Total NAS WITI used to qualify a days as mild/moderate/severe weather
  - Percentile values of Center WITI used to classify regional weather

Cluster 13: Severe Weather Day



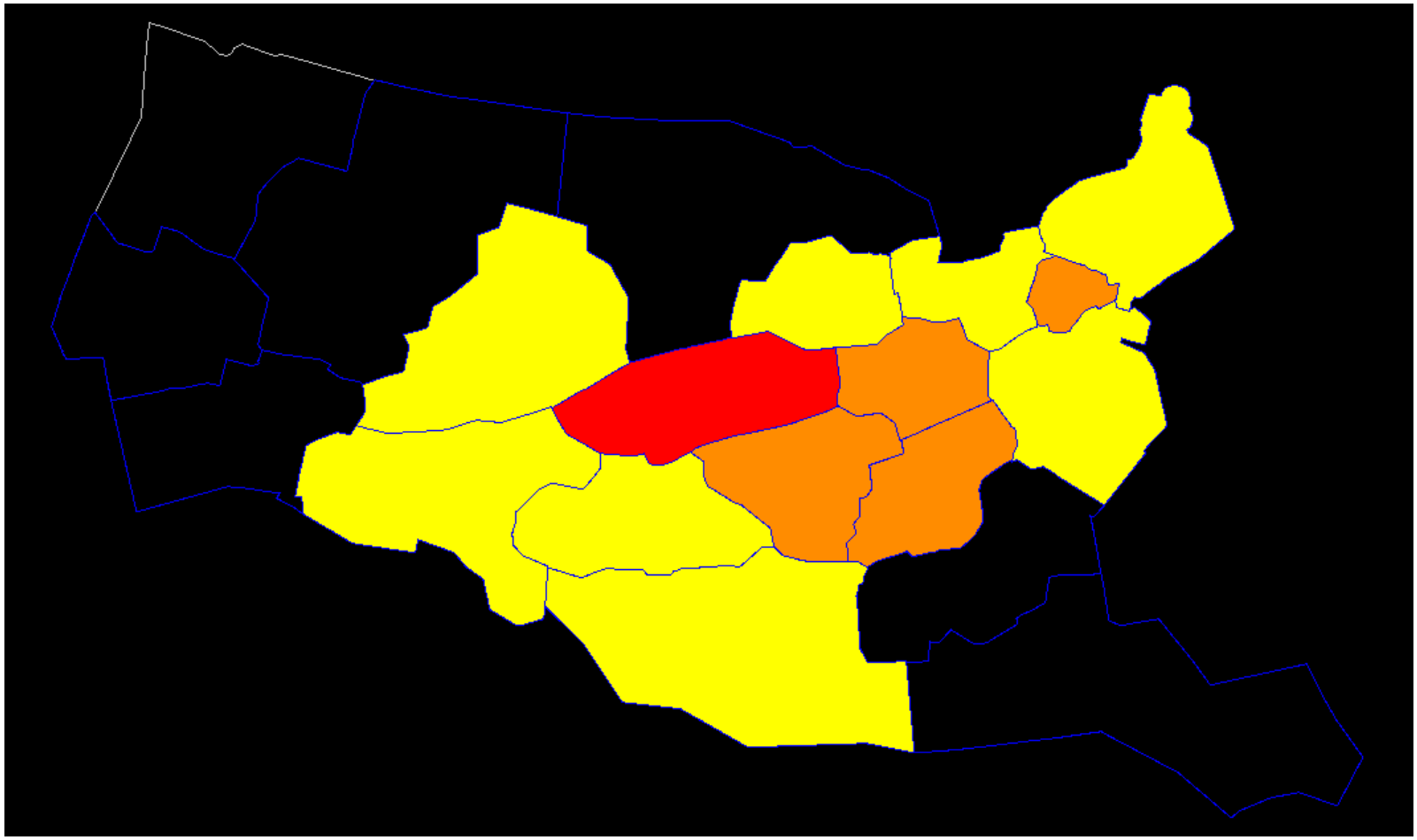
Number of Matching Days: 5

Cluster 12: Severe Weather Day



Number of Matching Days: 4

Cluster 11: Moderate Weather Day



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Weather Cluster to Reroute Mapping

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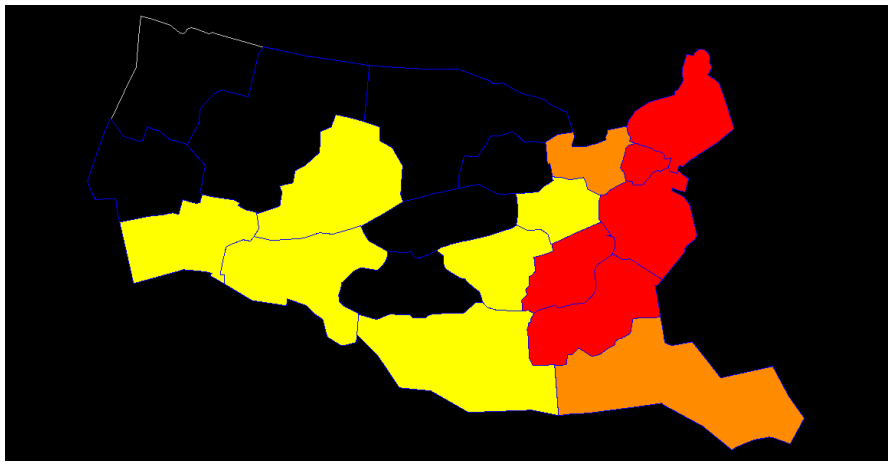

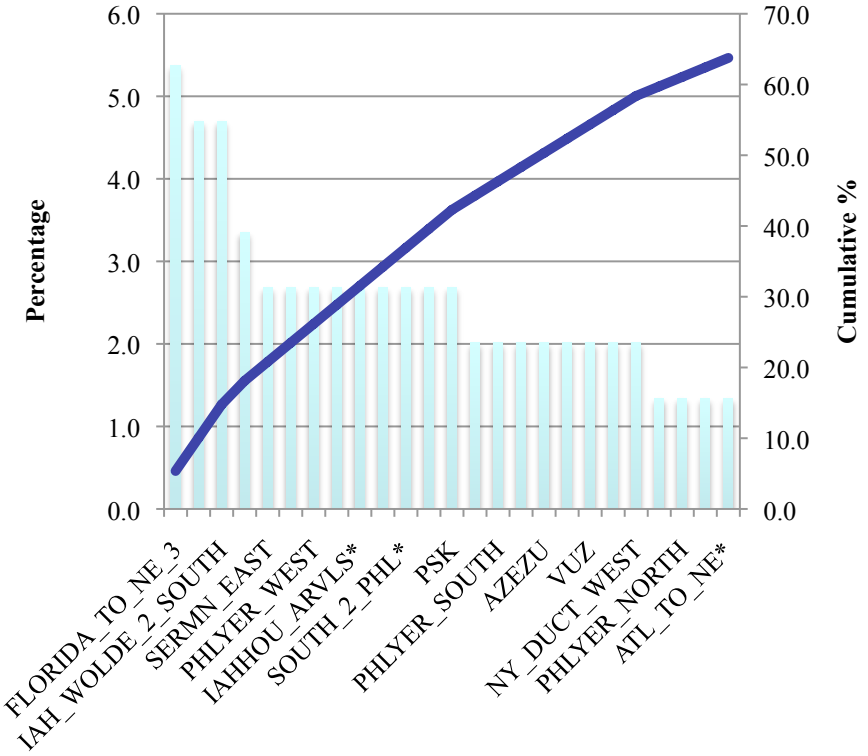

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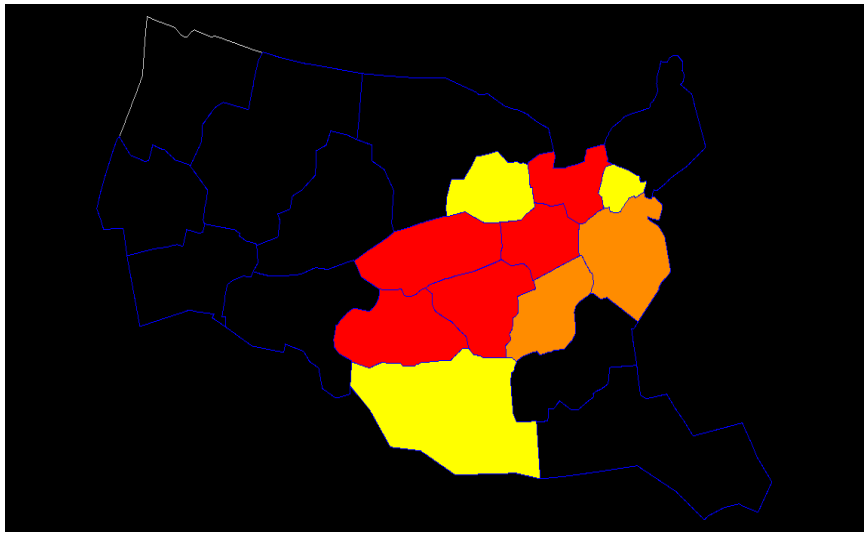

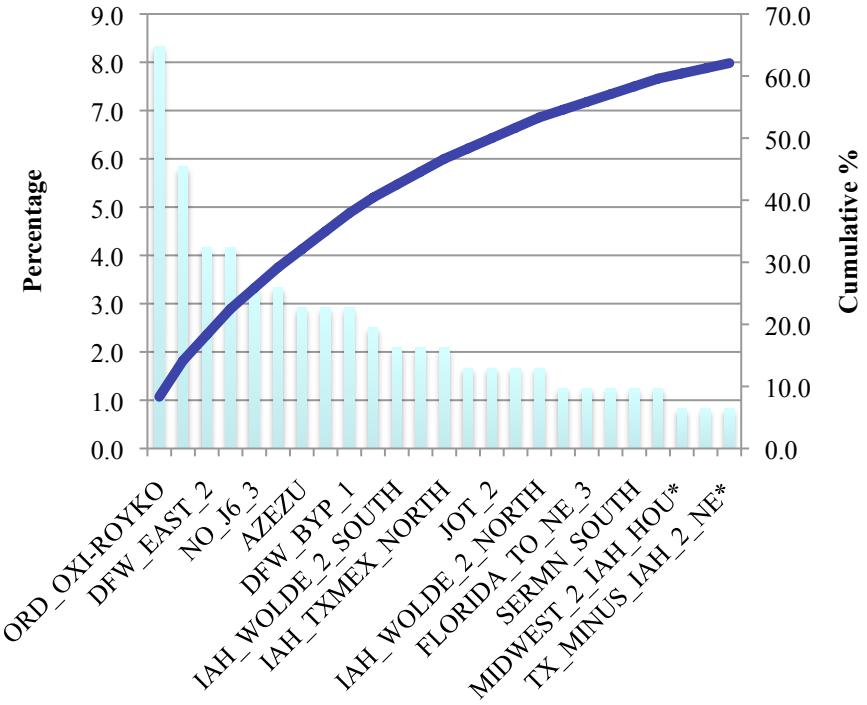

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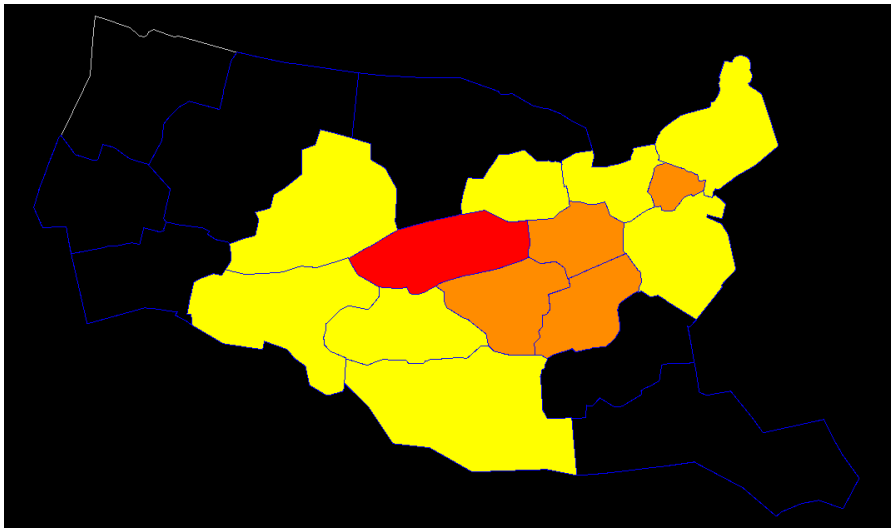

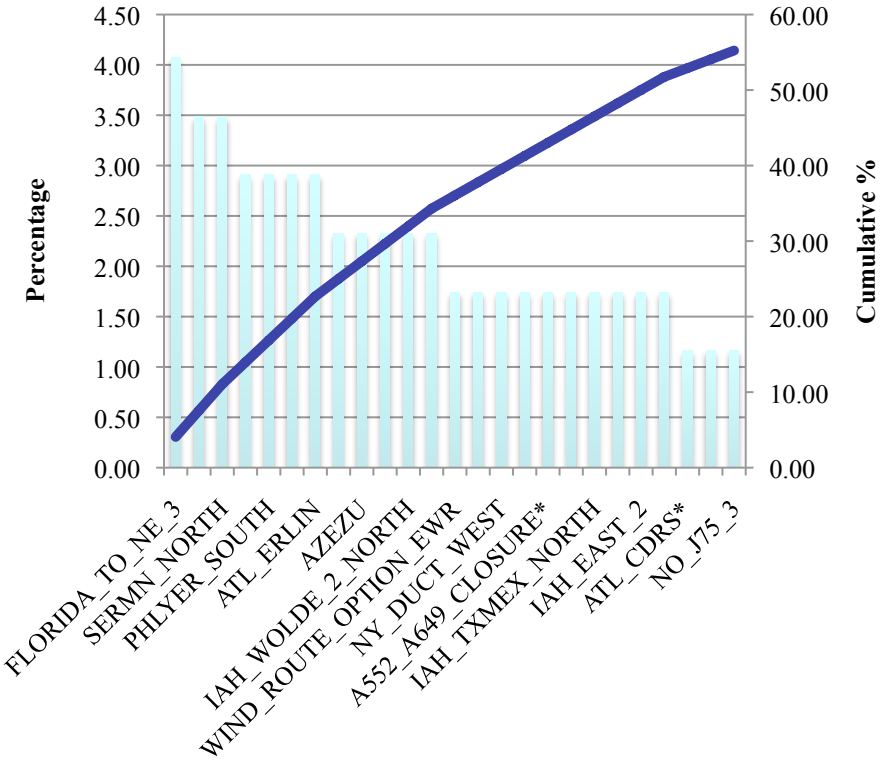

Approach

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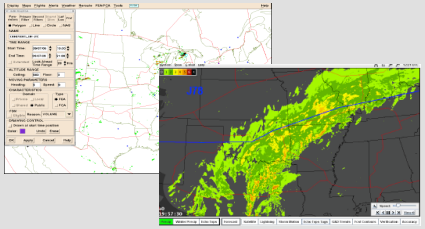
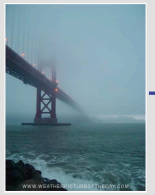
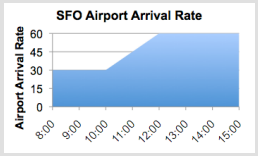
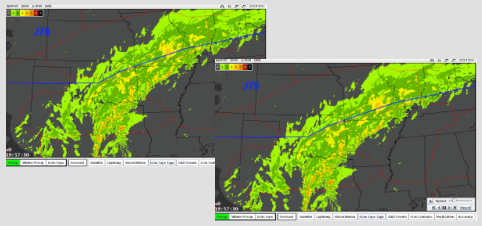


Airport and Airspace Weather Translation





Similar Days in the NAS



Historical TMIs

ATCSCC ADVISORIES FOR Monday, 06-18-2012

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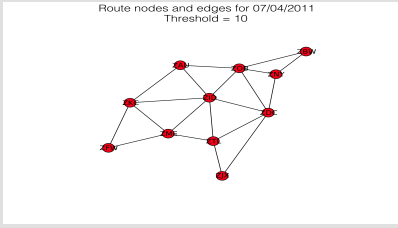

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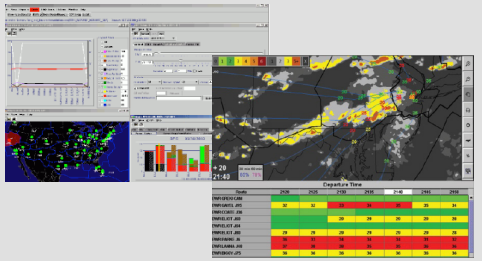

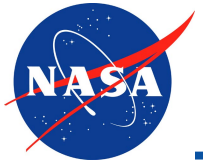

Historical Traffic Management Initiatives

NTML and the fly.faa.gov website are the primary sources of historical reroutes, MIT restrictions, AFPs, Ground Delay Programs and Ground Stops

- Much of the data is not directly machine readable

- This effort will ultimately be a client for the “TMI Cube” but currently much of the work is occurring in parallel

Approach

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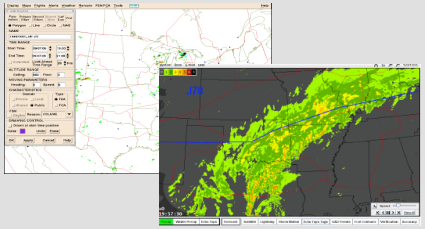

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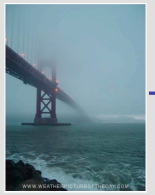

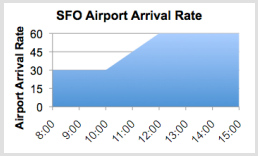

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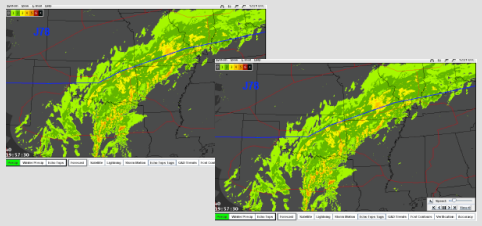

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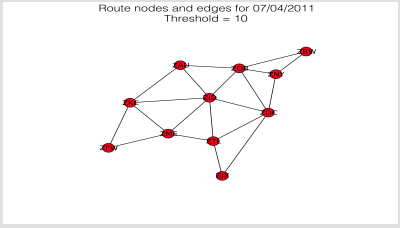
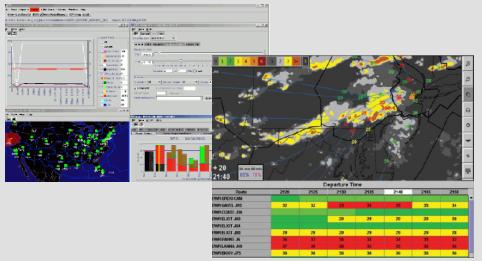
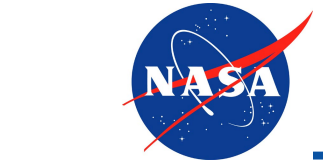


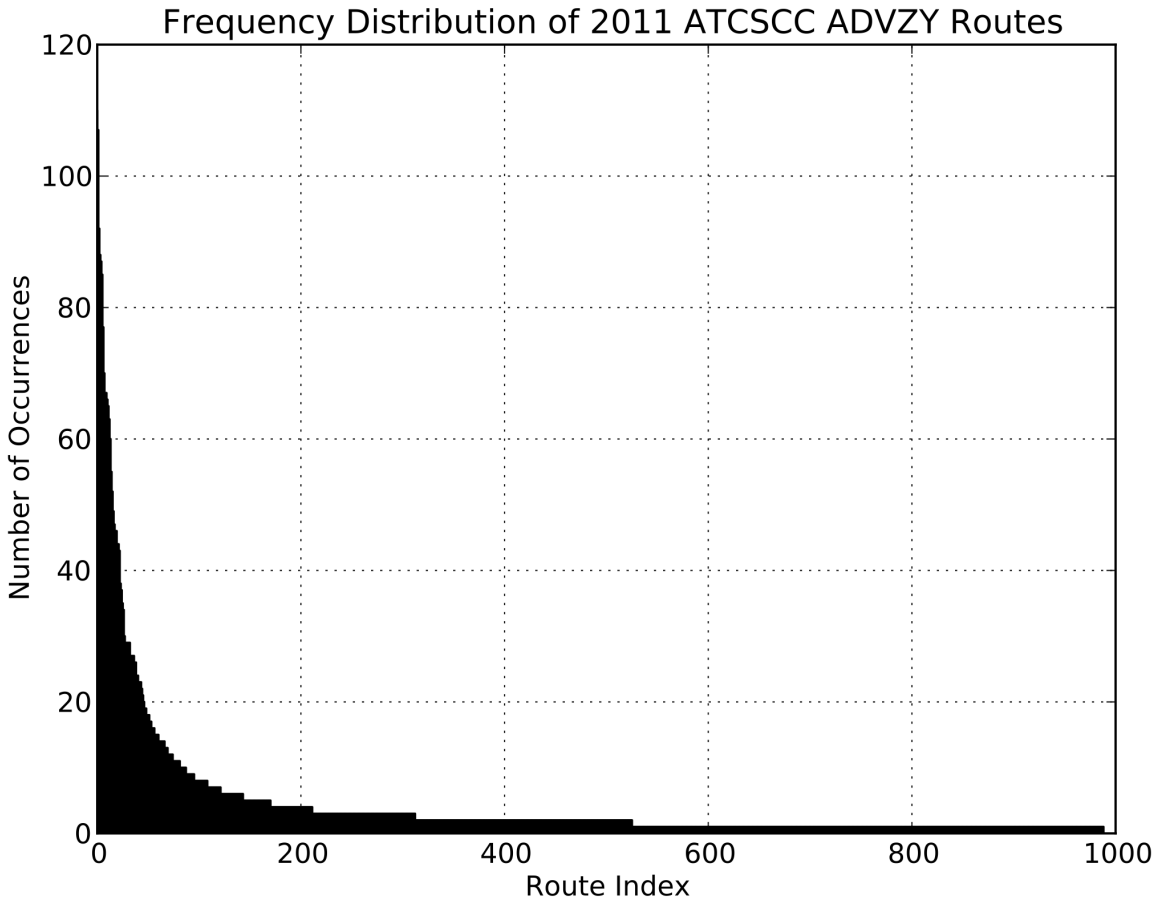
Network Representation of Reroutes

Similar TMIs used under similar days in the NAS





Reroute Data Reduction

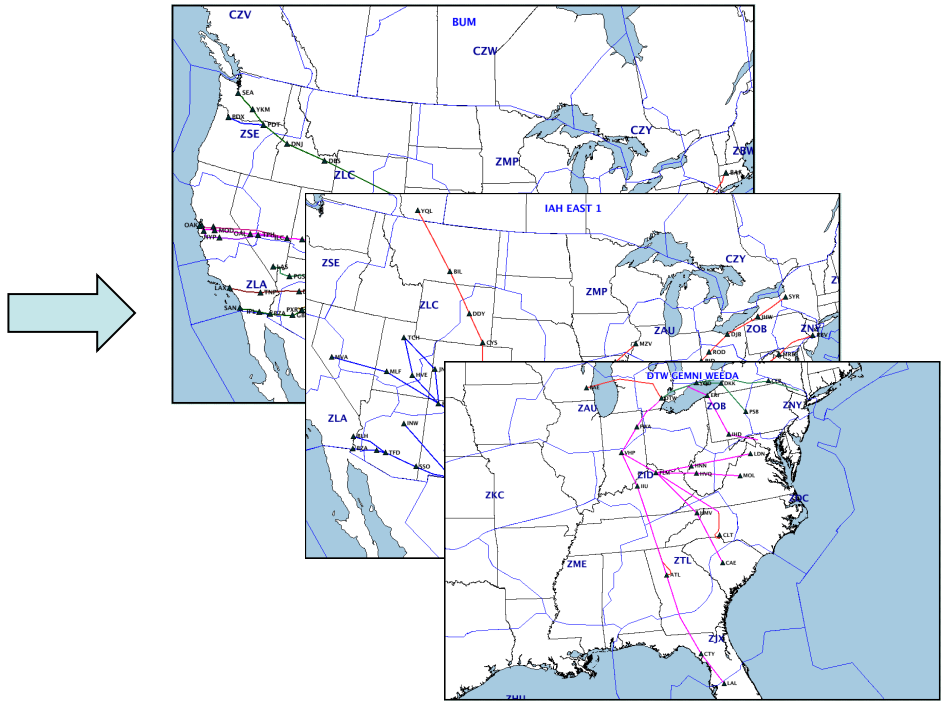


- 989 “unique” ATCSCC ADVZY reroutes issued in 2011
- Data reduction techniques required to reduce this number for describing the high-level, national-plan

Daily Reroute Clustering

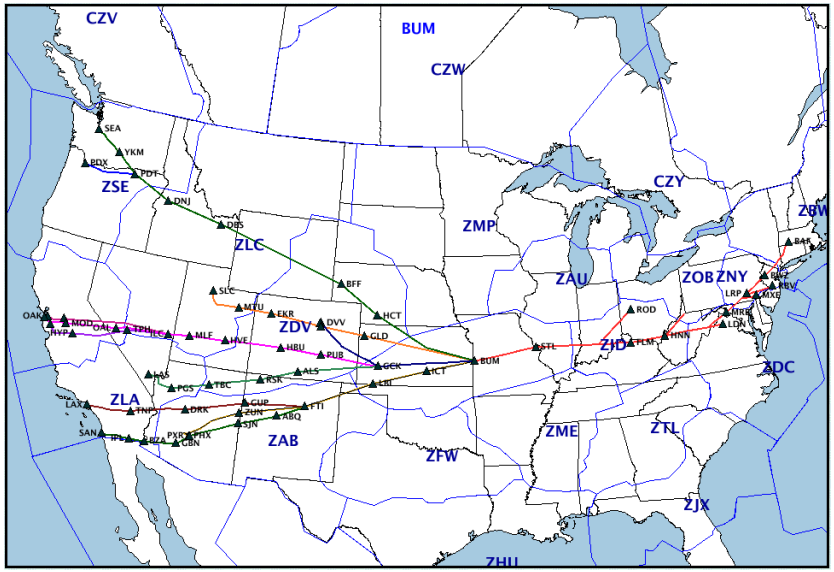
One technique to reduce the number of reroutes is to represent them in terms of a collection of pre-published playbook routes

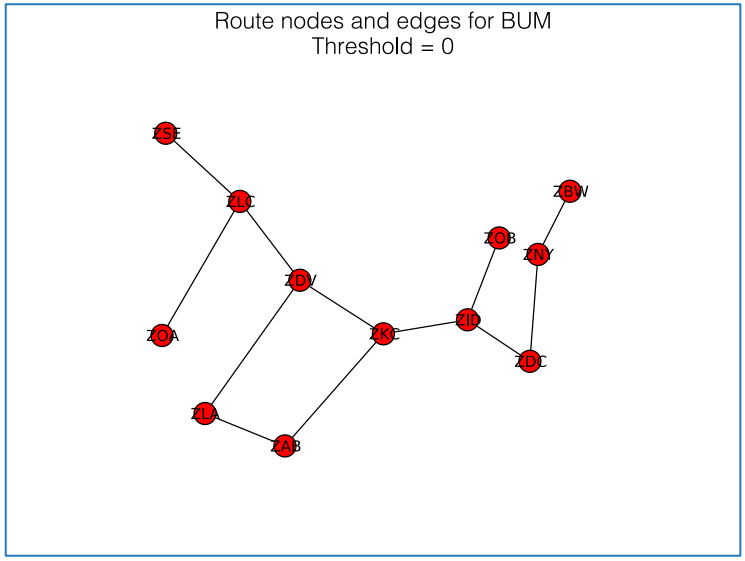
074	DCC	06/15/12	ATCSCC ADVZY 074 DCC 06/15/12 ROUTE RQD /FL NAME: BUM_PARTIAL CONSTRAINED AREA: ZKC/ZMP VALID: ETD 152226 TO 160100	06/15/12 22:29
073	DCC	06/15/12	ATCSCC ADVZY 073 DCC 06/15/12 ROUTE RQD /FL NAME: SE_2_SW CONSTRAINED AREA: ZHU VALID: ETD 152000 TO 160000	06/15/12 21:43
072	ATCSCC	06/15/12	OPERATIONS PLAN	06/15/12 21:35
071	DTW/ZOB	06/15/12	CDM GROUND DELAY PROGRAM	06/15/12 21:31
070	DCC	06/15/12	REROUTE CANCELLATION	06/15/12 21:29
069	DCC	06/15/12	ATCSCC ADVZY 069 DCC 06/15/12 ROUTE RQD /FL NAME: IAH_EAST_1_MODIFIED CONSTRAINED AREA: ZHU VALID: ETD 151830 TO 160100	06/15/12 21:10
068	DCC	06/15/12	ATCSCC ADVZY 068 DCC 06/15/12 ROUTE RQD /FL NAME: DTW_NO_WEEDA CONSTRAINED AREA: DTW VALID: ETD 152100 TO 160030	06/15/12 21:04



Center Representation of Playbook Routes

• There are over 200 playbook routes, so clustering the routes would improve computation performance
• One approach to clustering routes entails representing each route in terms of the Centers which they pass through





List of all possible NAS network edges: ZSE-ZOA, ZOA-ZLA, ZSE-ZLC, ZOA-ZLC, etc.
Network edges used by "BUM": ZSE-ZLC, ZOA-ZLC, ZLC-ZDV, ZLA-ZDV, ZLA-ZAB, etc.
Vector representing the "BUM" network edges: <0, 0, 1, 1, 0, 1,…>

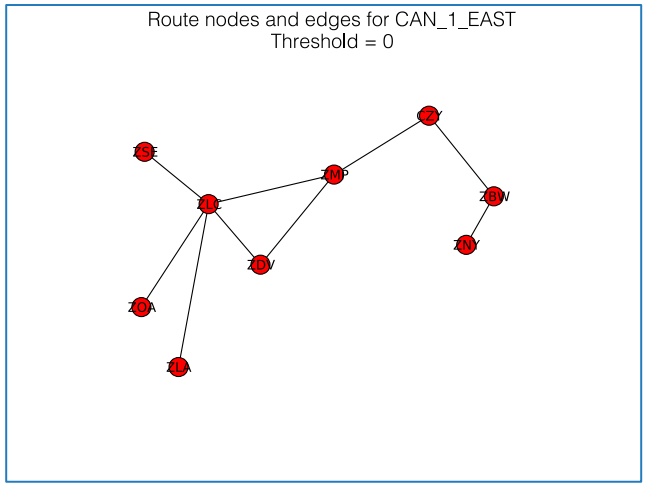
Playbook Network Clustering Approach

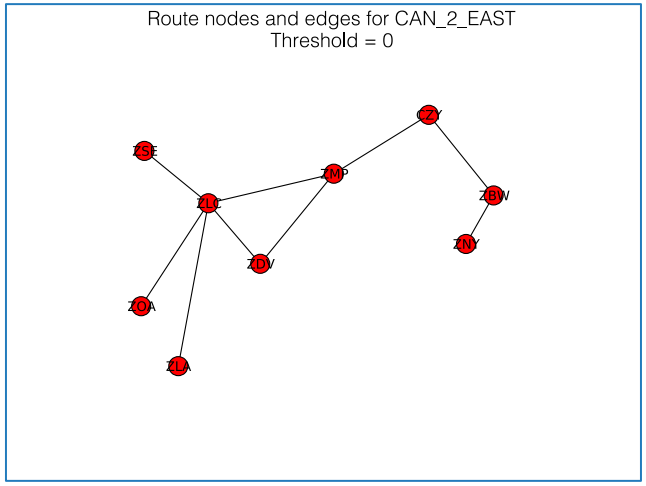
Candidate attributes of the playbook networks

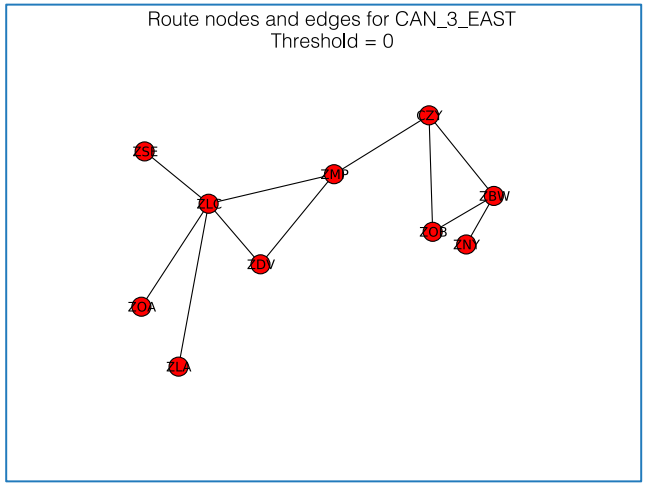
ZSE-ZOA	ZOA-ZLA	ZSE-ZLC	ZOA-ZLC	ZLA-ZLC	…	CZM-ZBW	Name
0	0	1	1	0	…	0	ATL_HONIE
0	0	1	1	0	…	0	ATL_NO_BNA
0	0	1	1	0	…	0	ATL_NO_MEM
0	0	0	0	0	…	0	ATL_TONIO
0	0	0	0	0	…	0	CVG_CINCE_1
0	0	0	0	0	…	0	CVG_CINCE_2
0	0	0	0	0	…	0	CVG_EAST

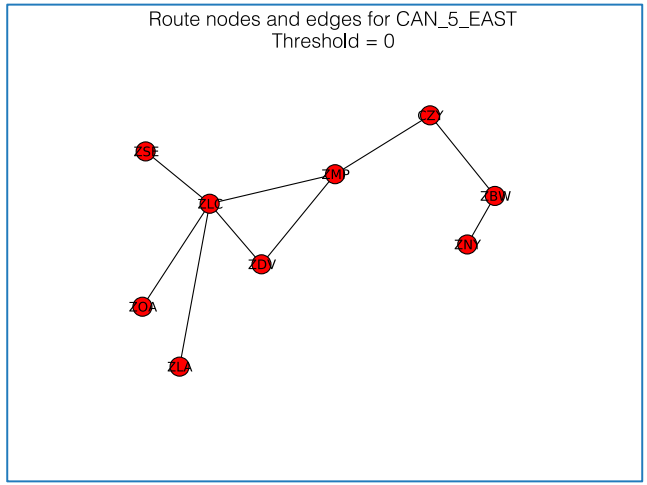
- K-means algorithm used to cluster the playbook routes
- Number of clusters determined by maximizing the average silhouette score of all clusters
- Clustering reduced the number of routes from 200+ to 17 playbook clusters

Sample members of “Cluster 3” - 7 members in cluster



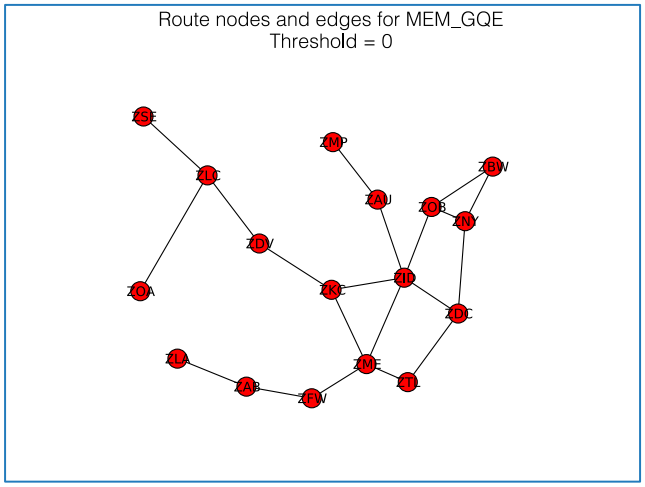


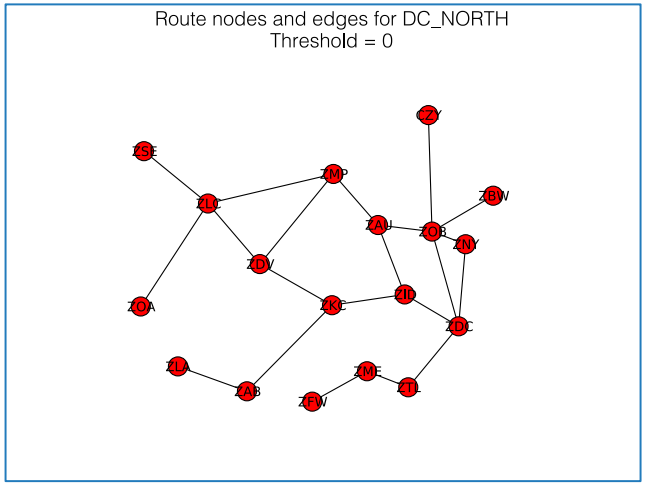


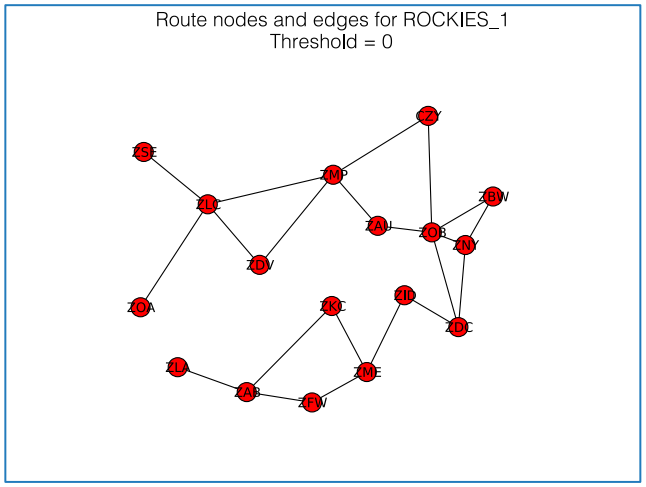


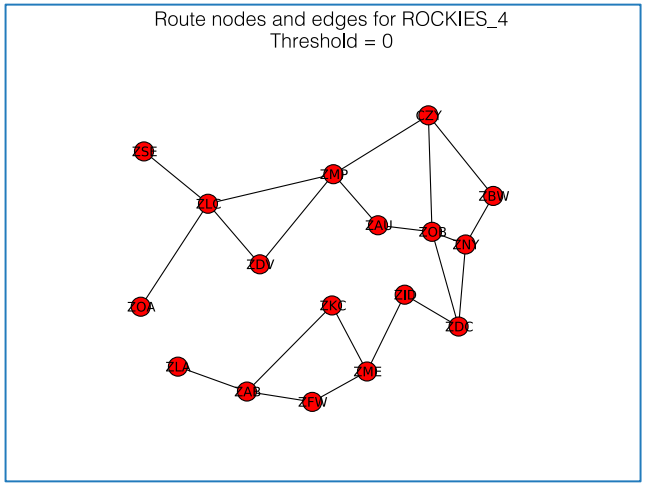
CAN East Routes

Sample members of “Cluster 4” - 4 members in cluster



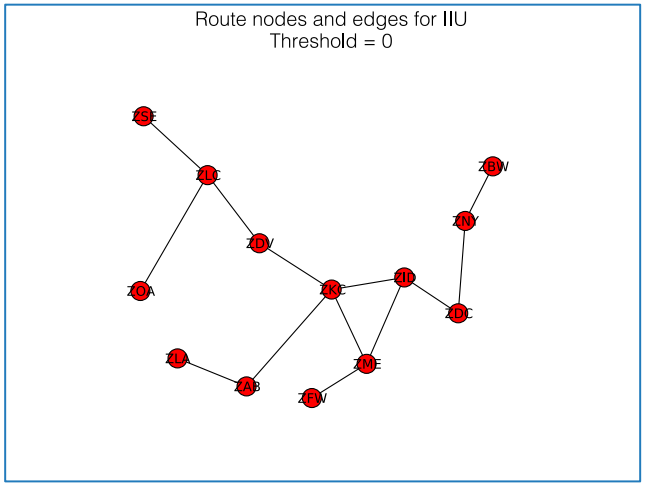


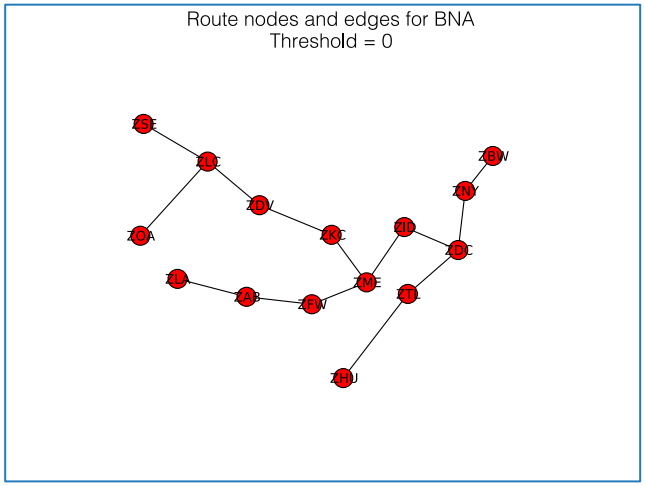


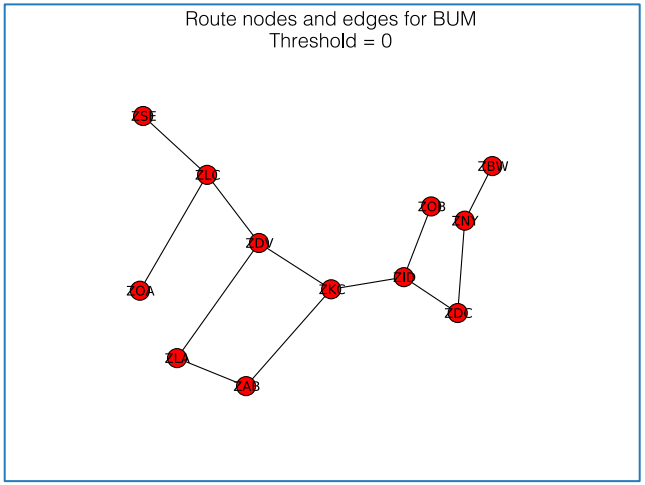


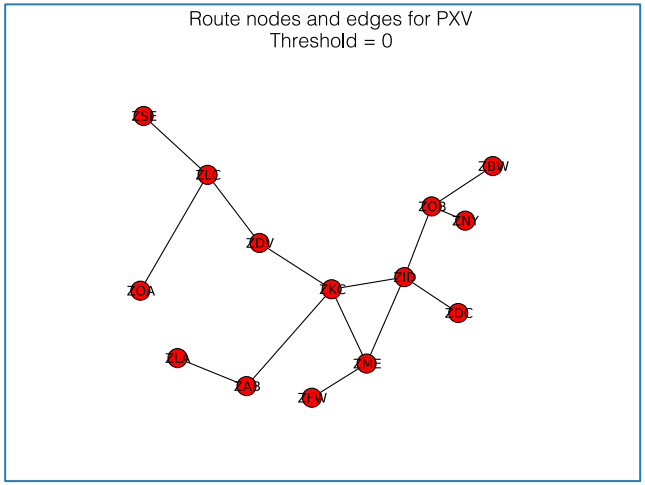
East to West Routes

Sample members of “Cluster 6” - 18 members in cluster









West to East Routes

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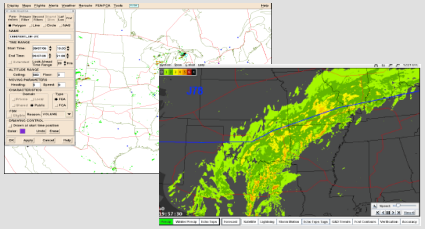

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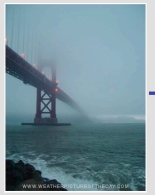

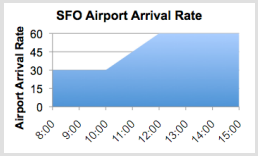

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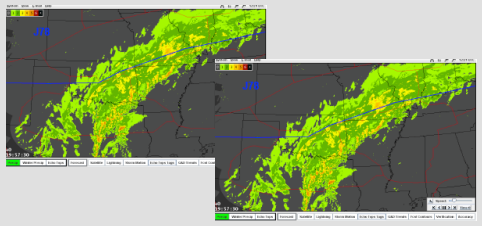

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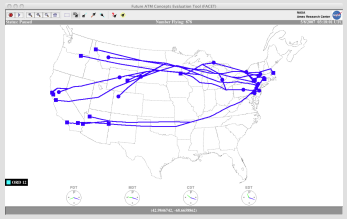

Grid-based Representation of Reroutes

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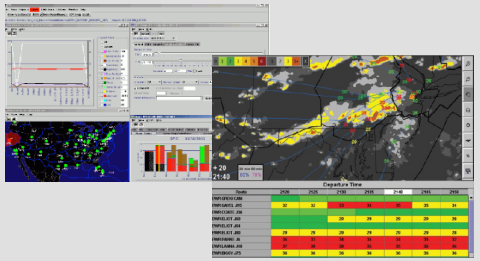
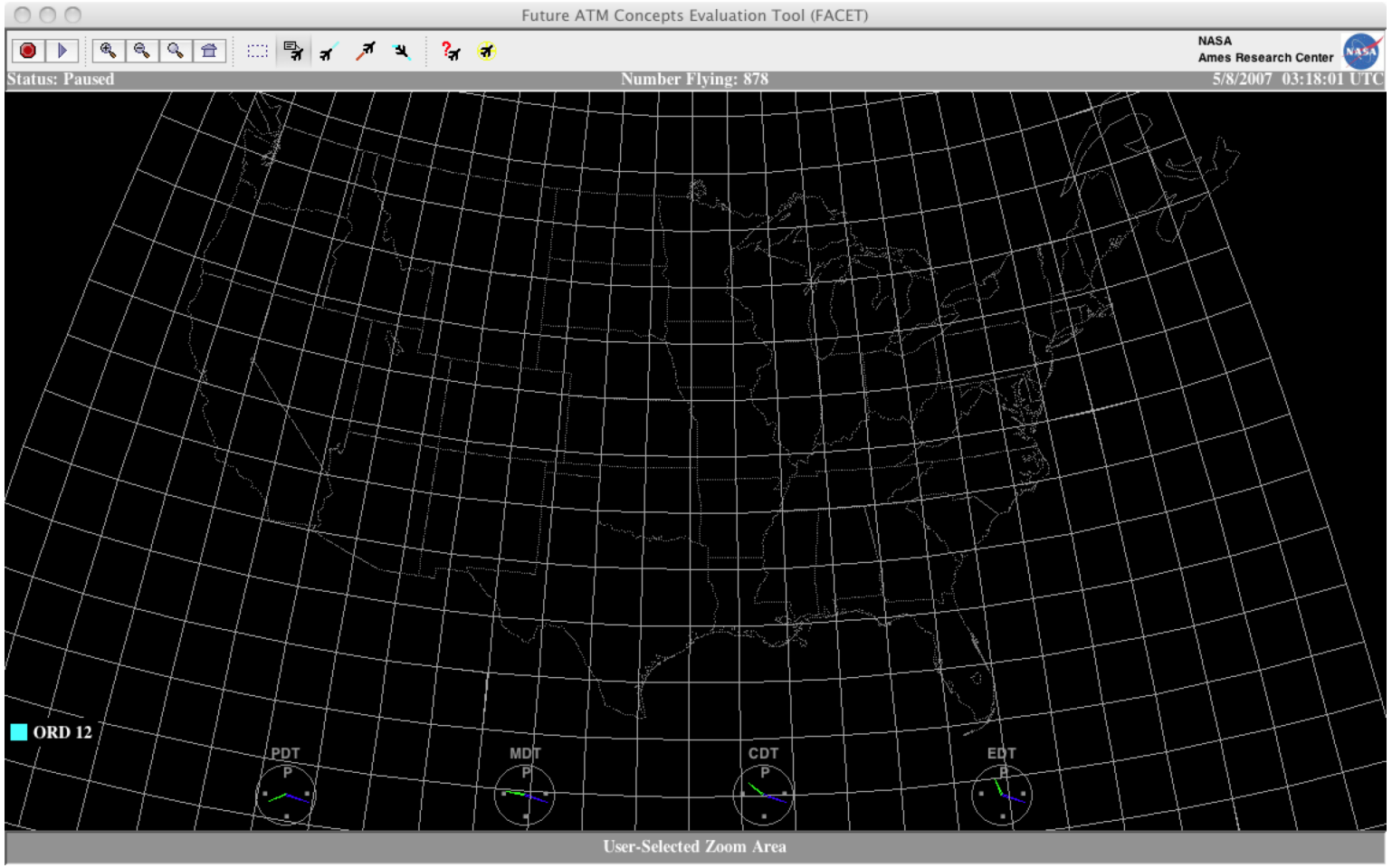


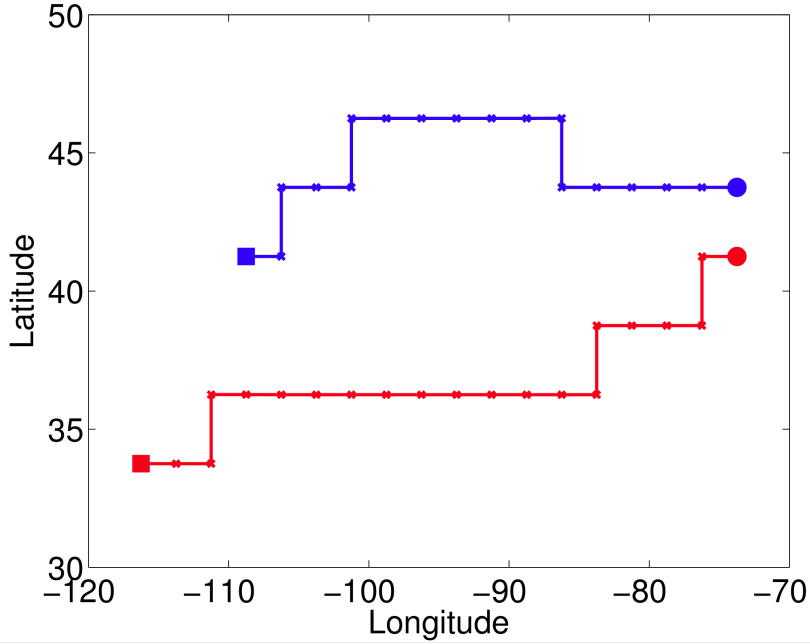
Reroute Data Reduction

Historical reroutes mapped onto a uniform grid to facilitate clustering, as part of the "Regional Plan"

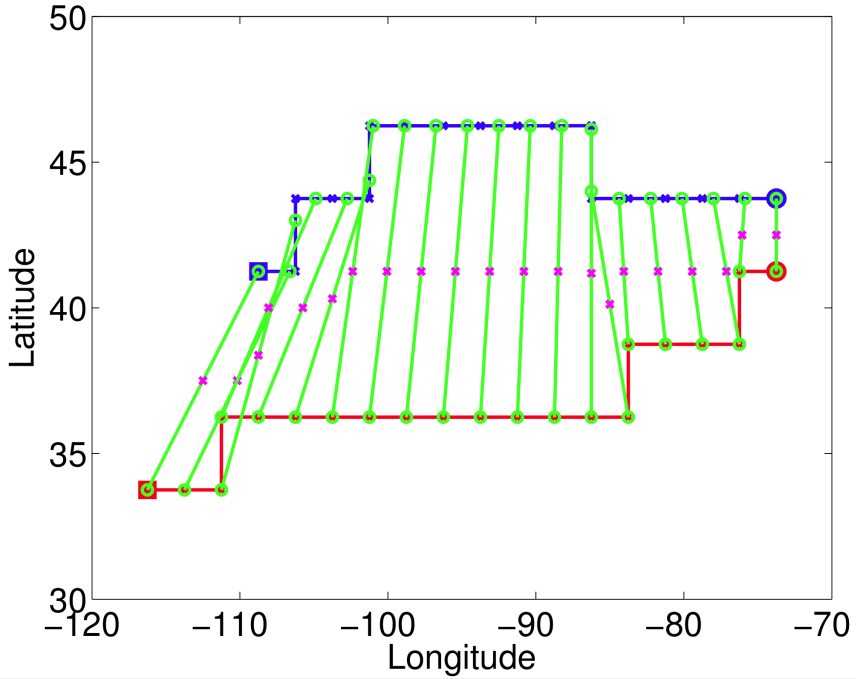


Sample Grid-based Routes

Sample Reroute
Start at circle end at square

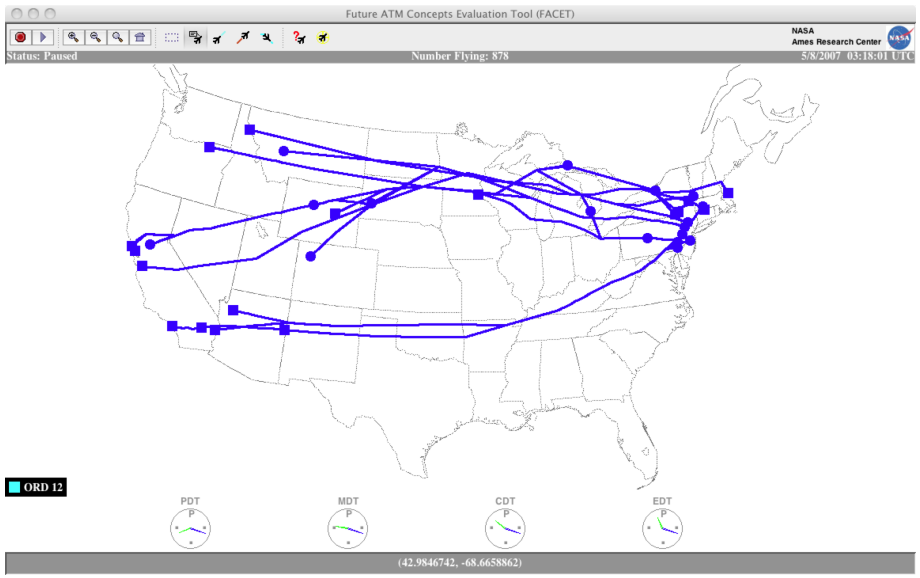


Route nodes compared
when clustering

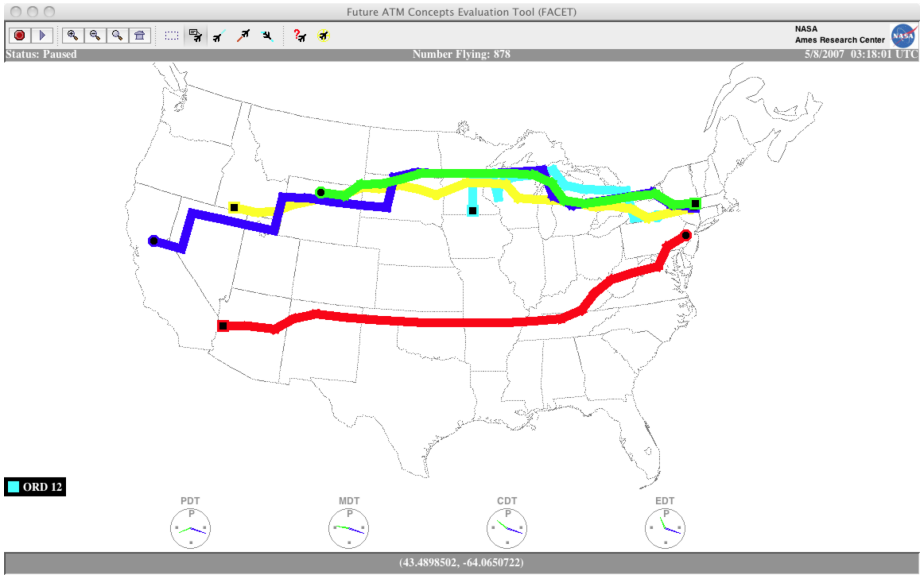


Test Scenario

53 un-clustered routes,
start at circle end at square

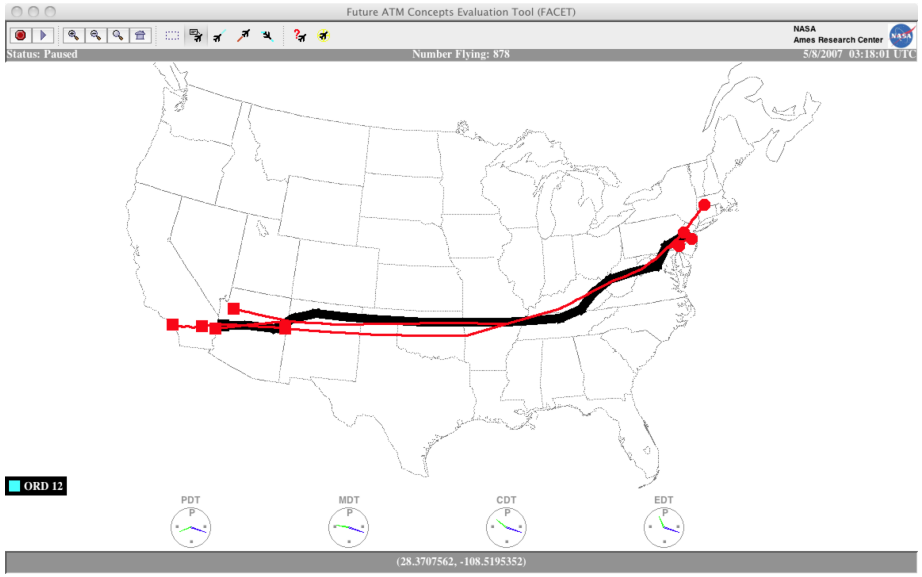


Five Route Clusters

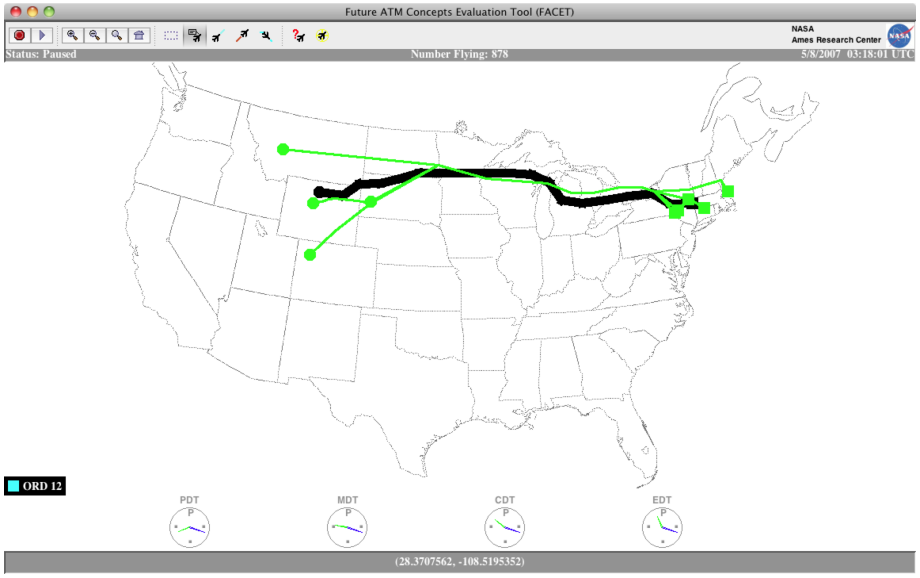


Routes clustered using a k-means clustering algorithm

Sample Reroute Clusters

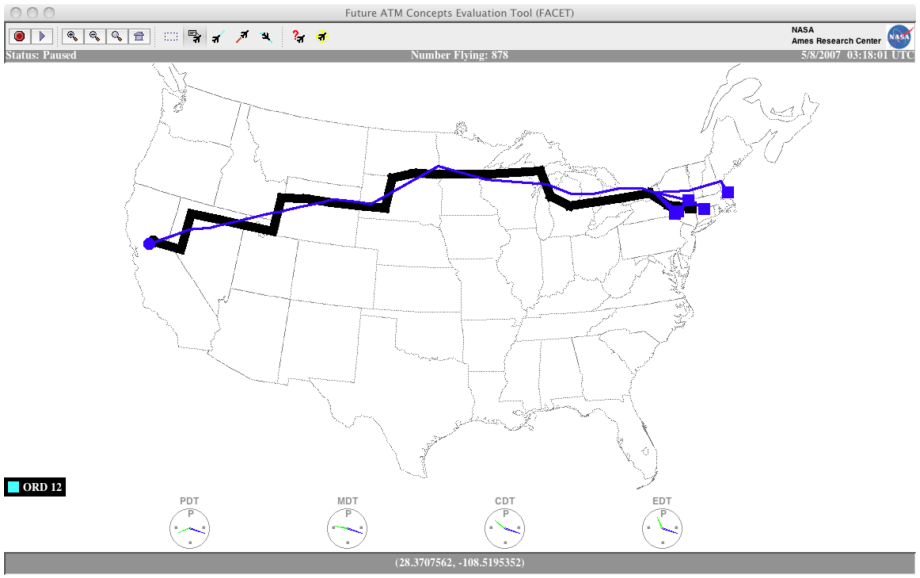


Cluster 1

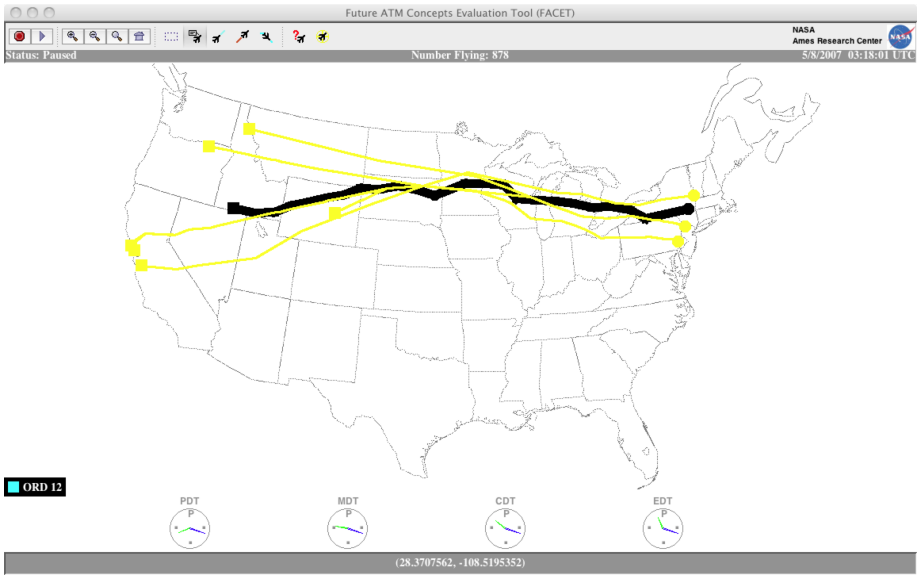


Cluster 2

Sample Reroute Clusters



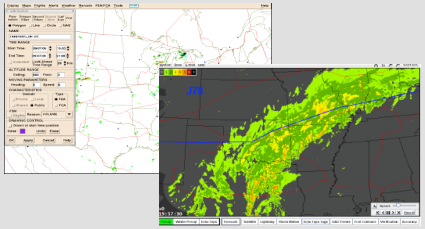
Cluster 3



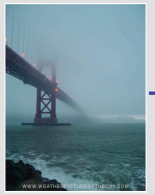
Cluster 4

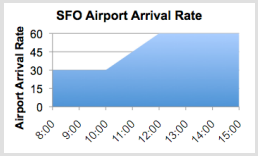
Approach

Historical NAS Status, Weather and Traffic Information

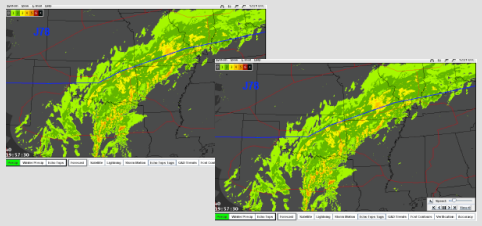


Airport and Airspace Weather Translation





Similar Days in the NAS

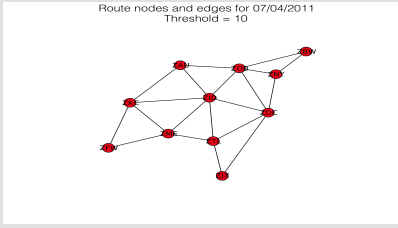


Historical TMIs

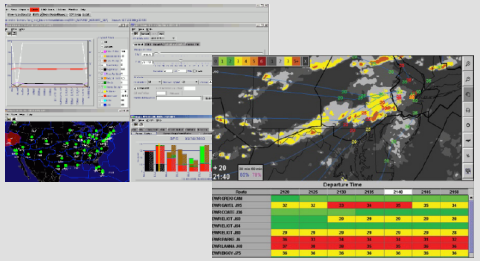
ATCSCC ADVISORIES FOR Monday, 06-18-2012

NUMBER	CONTROL ELEMENT	DATE	BRIEF TITLE	SEND TIME
107	DCC:	06/18/12	CDM GROUND DELAY PROGRAM CNX	06/18/12 23:51
106	ORD/ZAU	06/18/12	CDM GROUND DELAY PROGRAM	06/18/12 23:45
105	BWI/ZDC	06/18/12	CDM GS CNX	06/18/12 23:44
104	DCA/ZDC	06/18/12	CDM GS CNX	06/18/12 23:42
103	IAD/ZDC	06/18/12	CDM GS CNX	06/18/12 23:41
102	MEM/ZME	06/18/12	MEMPHIS METERING_FYI	06/18/12 23:30
101	DCC	06/18/12	OPERATIONS PLAN	06/18/12 23:30
100	DCC	06/18/12	REROUTE CANCELLATION	06/18/12 23:17
099	DCC	06/18/12	REROUTE CANCELLATION	06/18/12 23:16
098	DCC	06/18/12	REROUTE CANCELLATION	06/18/12 23:03
097	DCC	06/18/12	REROUTE CANCELLATION	06/18/12 22:59
096	DCC	06/18/12	REROUTE CANCELLATION	06/18/12 22:59
095	DCA/ZDC	06/18/12	CDM GROUND STOP	06/18/12 22:53
094	IAD/ZDC	06/18/12	CDM GROUND STOP	06/18/12 22:52
093	BWI/ZDC	06/18/12	CDM GROUND STOP	06/18/12 22:52
092	DCC	06/18/12	REROUTE CANCELLATION	06/18/12 22:50

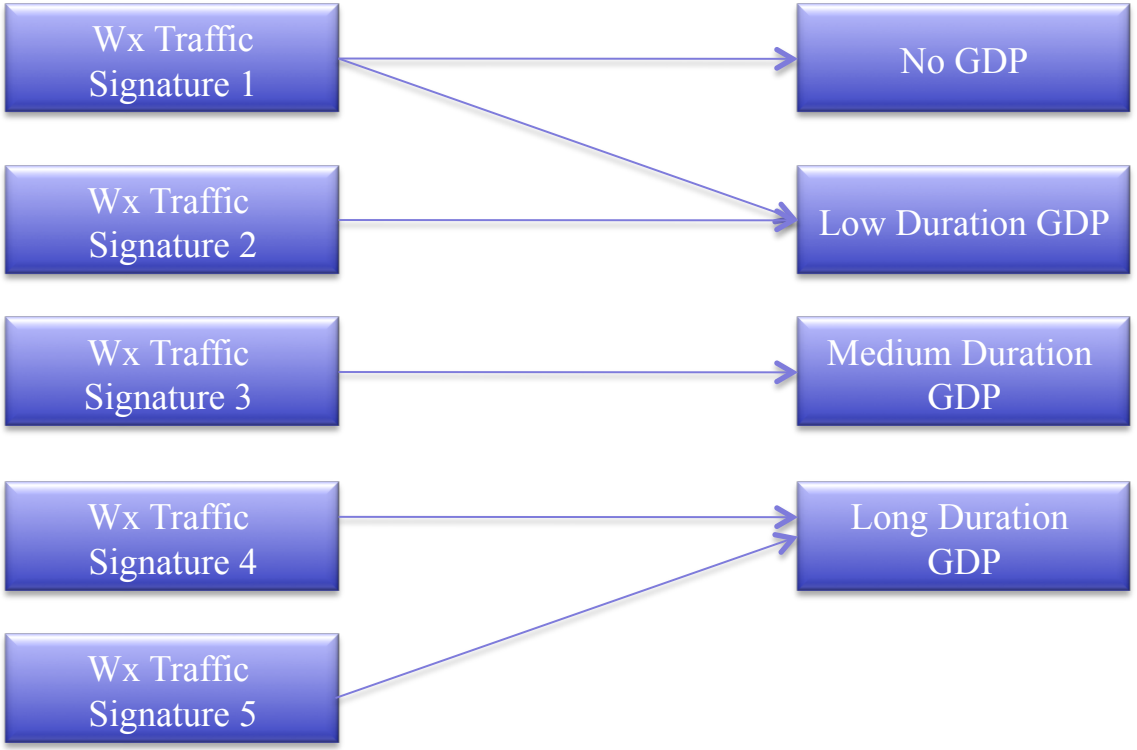
Parse/Aggregate/ Digitize TMIs



Similar TMIs used under similar days in the NAS



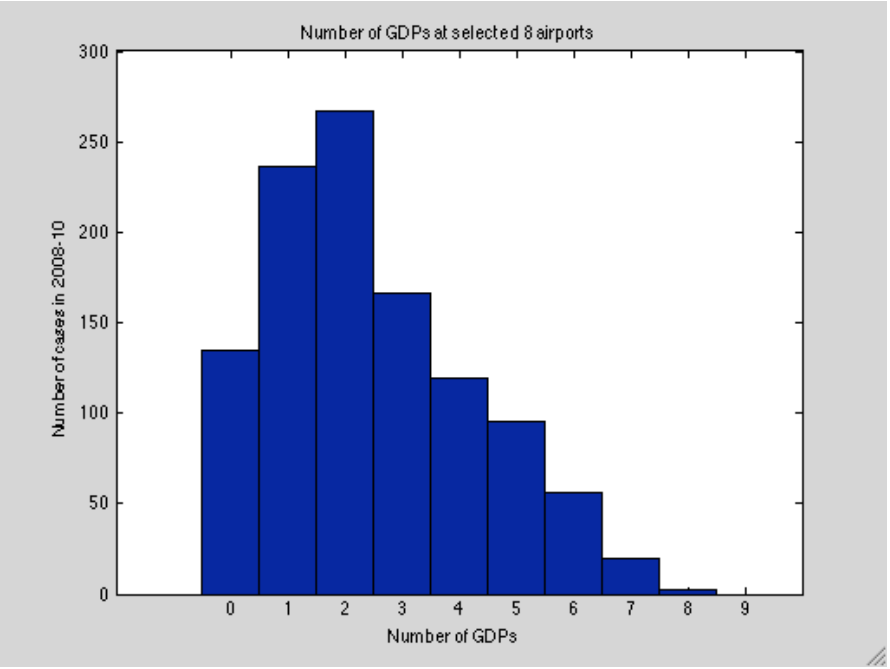
GDP Modeling Approach



- **Objective**: Develop decision association models based on historical data using data mining and other learning automation concepts
  - Given a weather disruption signature, what national plans consisting of GDPs were used in the past to deal with similar event?
- Data (NTML, ASPM, METAR from 2008-2010)
- Decision tree learning algorithms

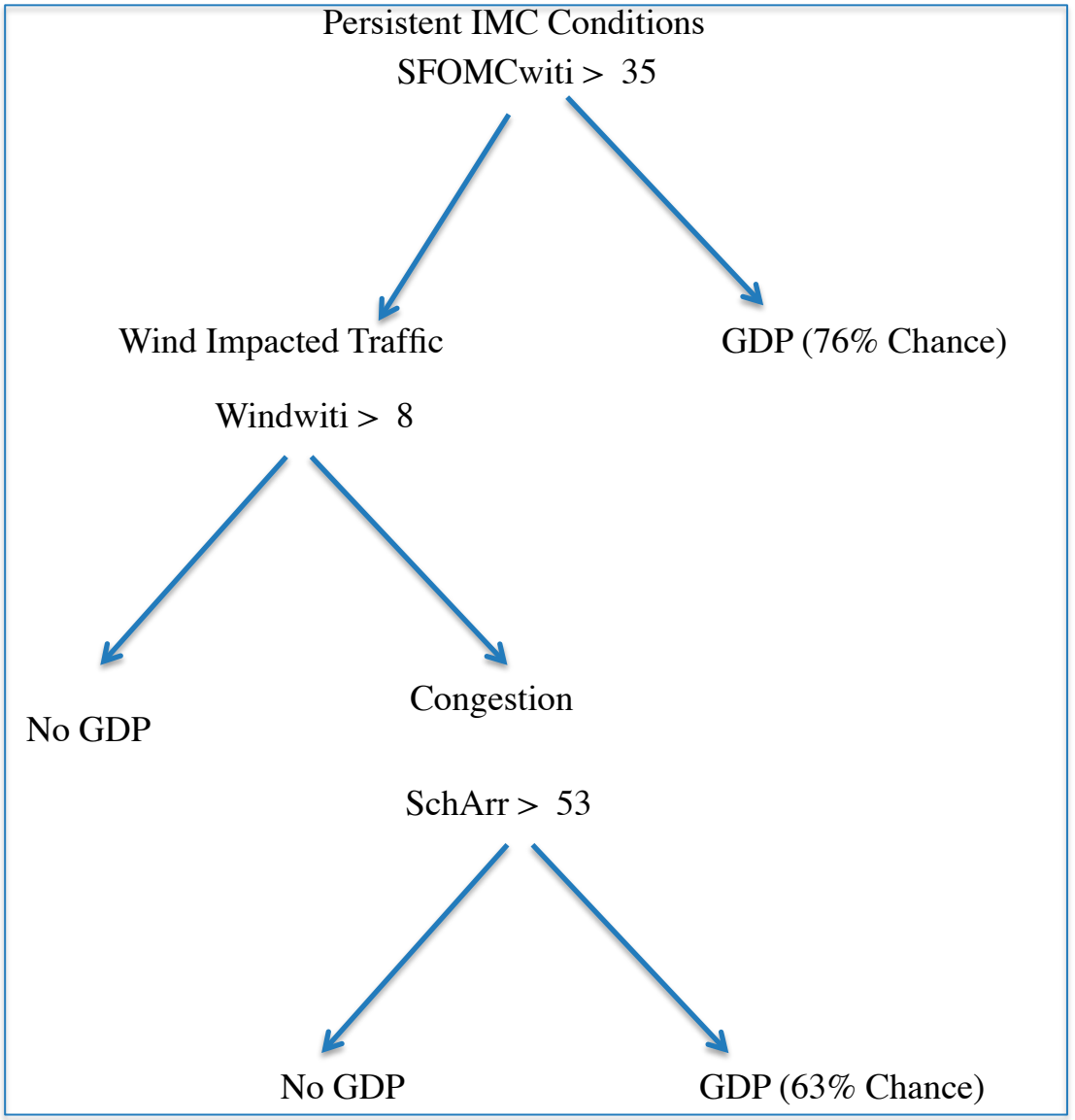
GDP Locations

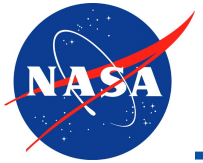
- GDPs at major airports (EWR, LGA, JFK, PHL, BOS, SFO, ATL, ORD):
  - Having GDPs at all 8 airports on the same day is rare,
  - 70% of the days have GDPs at more than one of these airports
- Developed two types of models
  - Models predicting GDPs at individual airports
  - Models characterizing interdependence between GDPs at different airports



SFO GDP Decision Tree

- Feature Selection: Best discriminating feature will produce sets with high probability of a control action.
- Each path from the root of the tree to a leaf represents a weather signature.

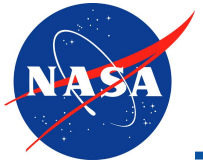




Capability 1: Predict GDPs at individual airports under specified conditions

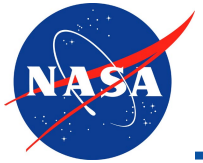
For weather signature on 12/11/2010, what is the likely GDP plan based on the historical pattern of GDPs?

Airport	Predicted Probability of GDP	Actual GDP status
EWR	18%	No
LGA	14%	No
JFK	14%	No
PHL	43%	No
BOS	3%	No
ORD	53%	Yes
ATL	6%	No
SFO	86%	Yes



Capability 2: Capture interdependence between GDPs at different airports

- Predict number of GDPs in New York region
  - Likely number of GDPs in New York area is 3 on 12/12/2010 with probability of 65%
- Predict GDP patterns in New York region
  - Likely regional plan predicted with weather on 12/12/2010
    - 65% probability of GDPs at JFK, EWR, LGA
    - 9% probability of GDPs at JFK and EWR
    - 8% probability of GDPs at LGA and EWR
  - Likely regional plan predicted with weather on 12/15/2010
    - 32% probability of GDPs at JFK, EWR, LGA
    - 26% probability of GDPs at JFK and EWR
    - 22% probability of GDPs at LGA and EWR
    - 12% probability of GDP at EWR
- Predict Probability of a GDP at another airport given that there is a GDP at an airport
  - Northeast airport GDPs correlated with each other. This is partly because weather at these airports is correlated with each other.
  - Example: Conditional probabilities of GDP at other airports given that there is GDP at EWR are as follows:
    - LGA: 0.55 JFK: 0.56 PHL: 0.37 BOS: 0.32
  - In some airport pairs, there are temporal patterns regarding which airport has GDP first. For example, on days with both LGA and EWR GDPs, EWR first 45 days, LGA first 149 days

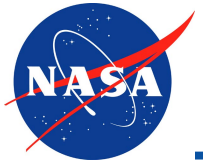


GDP Prediction Issues

- Understanding variation in control actions under similar weather conditions
  - Possible causes of variation may include controller subjectivity, differing goals, availability of alternate control actions / cancellations, missing information about impacting factors
  - Therefore, a study comparing official GDP causes with historical patterns in decision trees on days with following weather signature was done.
    - Visibility < 3.5 nm, wind speed < 11, number of GDPs in rest of North East USA major airports < 3
    - Likely Control Action on these days is GDP

Days with Low visibility

Date	MCWiti	Highwind witi	Vis	Ceil	Scharr	MC	Wsp	North East GDP	Actual GDP	GDP cause
2/4/08	39	0	1	700	24	1	6	2	1	Low vis
2/6/08	11	8	3	1600	23	2	7	2	1	Wind
2/17/08	23	0	2	600	22	2	6	0	0	
2/23/08	30	0	2	700	20	1	9	1	1	Low Ceiling
2/29/08	4	6	0	500	25	2	9	0	0	
4/5/08	9	8	2	2200	20	2	11	0	0	
4/9/08	24	0	1	300	25	2	4	2	1	Low vis
4/10/08	9	0	0	200	26	1	5	2	0	
4/12/08	10	24	0	200	20	1	10	0	1	Wind
5/3/08	41	0	0	300	20	1	9	1	1	Low vis



GDP Analysis

- Probabilistic GDP predictions are accurate within 10% accuracy.
- Actual cause is attributed to a single weather factor such as wind, ceiling or visibility whereas some of the days have multiple adverse factors. Decision tree signature patterns often include more than one factor.
- We do not have data on some of the GDP causes such as ‘runway construction and maintenance’
- In some cases, data we have does not explain stated GDP causes. For example, 2/6/2008 seem to have low visibility conditions and low wind speed conditions at EWR. While existence of GDP on that day is consistent with historical pattern, the attribution of GDP cause to wind is puzzling.